Semi-DHCAL software developments: Digitization and Display

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GRPC Semi-Digital HCAL is a solid option for the PFA oriented calorimetry of the International Linear Collider. Together with the hardware, the software developments is progressing steadily. The stauts and plans for the GRPC SDHCAL software development are presented, as well the first order digitization module for the GRPC and the display program DRUID (Display Root module Used for ILD) have been introduced.

1 Introduction

The Semi-Digital Glass RPC technology is a solid option for the ILD detector, because the RPC is a well-understood technology with many advantages, such as high efficiency, homogeneous, robust and low cost; as a gaseous detector, the RPC is almost free of neutron hits; and most importantly, the semi-digital technology codes every channel with only two bits, allows a granularity as high as 1 channel per square cm with relatively low electronic cost. Good performance is expected in jet energy resolution.

The GRPC SDHCAL (GRPC Semi-Digital HCAL) group is an international collabration consists of more than ten institutes. The aim is to have a good understanding to the GRPC SDHCAL detector and to proof the GRPC SDHCAL is a feasible option to the ILC detector.

In order to understand the detector performance and to optimize the experimental setting, prototypes (see Fig. 1) are constructed and tested with various options. We have the so called mini-DHCAL with 1k channel, the square meter with 10k channel, and the ANR cubic meter with 400k channel is under constrtuction. Lots of new technologies will be tested on the cubic meter, such as power pulsing, embedded electronics and self-supporting mechanics. Besides, the analysis of the test beam data will be used to validate the Geant 4 hadronic simulation.

Now let's start from an introudction on the status and plan of GRPC Semi-DHCAL softwares.

1.1 Staus and plan for the GRPC SDHCAL softwares

As well as for the hardware, the GRPC SDHCAL group has made great efforts on the software development.

For the test beam experiment, a software chain (DAQ, reconstruction, analysis) based ROOT has been developed. The data format will be updated to LCIO standard, and currently people are focusing on the R & D of the new DAQ system.

A Geant 4 simulation package with the cubic meter prototype geometry has been developed, and a valid concept for the ILD with a la Videau DHCAL Geometry and GRPC sensor layer is currently availalbe in Mokka, the standard ILC detector simulation software.

*On the behavior of SDHCAL collabration

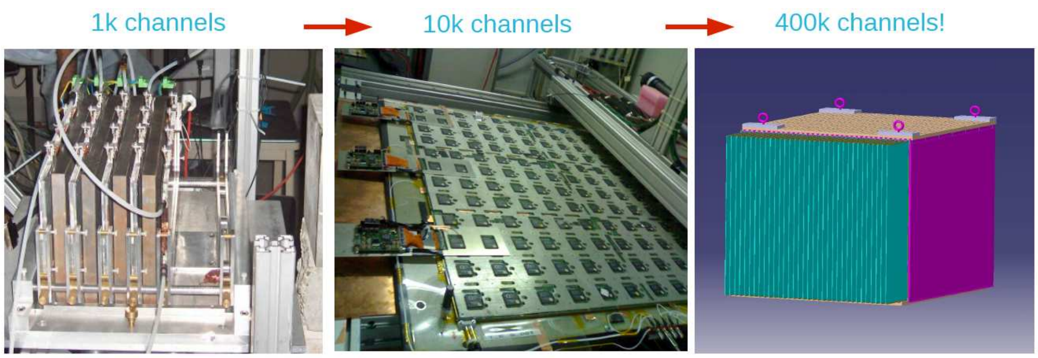


Figure 1: GRPC SDHCAL Prototypes: mini-DHCAL, square meter and ANR cubic meter

The digitization is important for the GRPC SDHCAL, as we believed the semi-digital option could kept more useful information than the pure digital HCAL. A first order digitization module with the cosmic ray experimental input has been developed, which converts the shower particle energy deposition in each cell to the quantity of induced charge on the electrinic nodes. Preiliminary result is optimistic. The digitization module has been integrated into standard Marlin framework, and it will be upgraded with multiplicity and saturation correction.

Because GRPC SDHCAL utilises totally different technology and detector geometry comparing to the AHCAL concept, its reconstruction algorithm need to be developed and optimized, which is regarded as one of the central task for SDHCAL software development. People are studying the hadronic shower development, aiming at develop an optimized reconstruction algorithm for the GRPC SDHCAL. The idea is to integrate the SDHCAL reconstruction algorithm into the full Pandora reconstruction chain [1], to achieve the best performance in jet energy resolution.

A 3d display program DRUID based on root [2] TEve class (developed for the LHC event display) has been developed. It can visualize the information stored in standard ilc data file (slcio file) with various options and different detector geometries. With DRUID, better understanding of the ILD/test beam event and reconstruction algorithm performance could be achieved. Some examples are given in the following section.

Central MC generation with particle gun events and ILC benchmark physics processes is also proposed, which will server as a basis for the algorithm development, performance analysis and geometry optimization study.

Now let's fouse on the software tools of digitization and display.

2 Digitization module for GRPC SDHCAL

The digitization module is important for the GRPC SDHCAL option since people are eager to know if the SDHCAL option could successfully record more useful information than DHCAL.

As shown in Fig. 2, a cosmic ray experiment has been performanced. Using the scintillator as trigger, the anaylog readout of one channel has been recorded, and reconstrued into the induced charge spectrum with about 2700 cosmic ray events. The induced charge

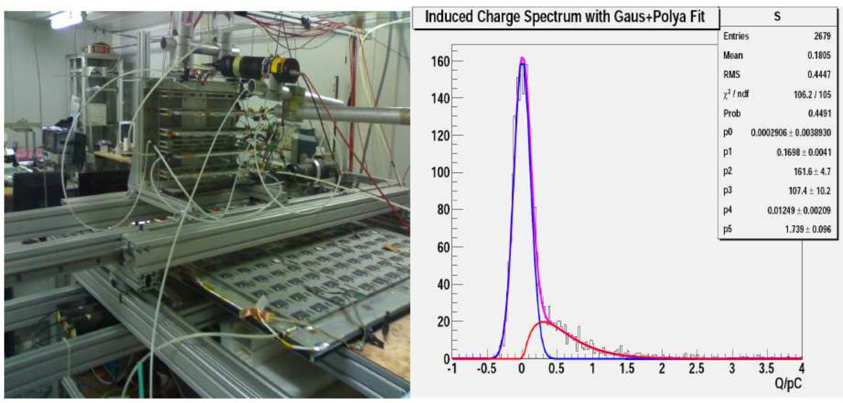


Figure 2: Cosmic ray experiment and Induced charge spectrum

spectrum could be fit to a Polya function as signal and a Gaussian pedestal noise. The fitted parameters of the spectrum are used as the input for the digitization.

The method of digitization is straightforward. First, readout the Monte Carlo truth information of energy deposition from simulation; second, estimate the number of ionizations that will be generated according to the energy deposition. The induced charge to one individual ionization is estimated from a Polya function (with the parameters calculated from the experimental input). And the total induced charge is assumed to be sum of the charge of all the ionization.

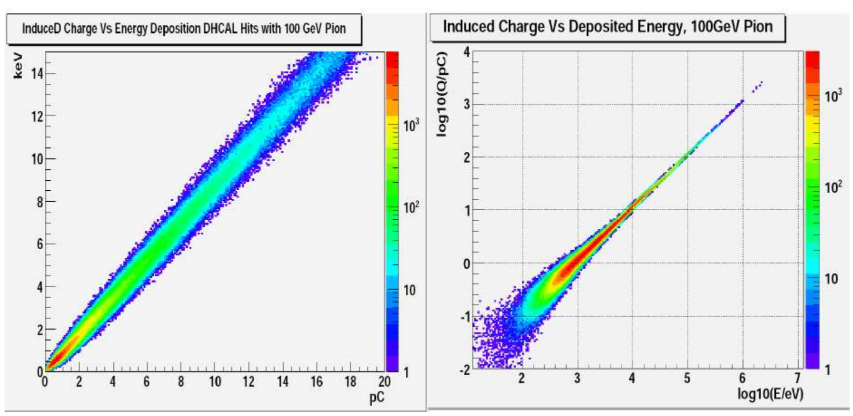


Figure 3: Correlation between induced charge and deopsited energy for 100GeV Pion

The correlation of induced charge and deposited energy is shown in Fig. 3. Because of large uncertaintly of the RPC avanache development, there is large smearing in charge inducing at low energy deposition region, but statistically nice correlation has been observed at high energy deposition region, where the induced charge could successfully represnent the energy deposition information. In other word, SDHCAL do keeps more energy information comparing to the pure DHCAL.

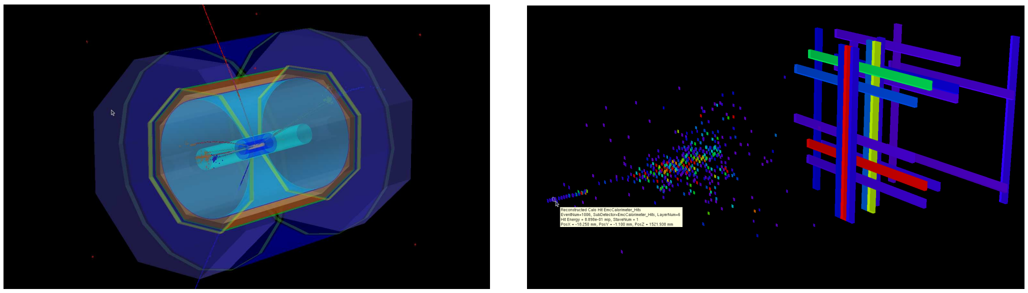


Figure 4: **Left:** Simulated ZH event at ILD detector **Right:** Reconstructed CALICE test beam event

The current digitization module has not taken into account the multiplicity and saturation effects. Those corrections will be included in a upgraded version.

3 DRUID: Displaying Root module used for ILD

Druid [3] is a 3d display program used to visualize information stored in standard ilc data file (slcio format). Currently it is specified to support the ILD geometries with gear file as geometry input file, and has been tested on simulated ILD event and CALICE test beam event (Fig. 4). According to different collections stored in the lcio file, Druid could display different objects in different combinations and styles.

Druid needs a pre installed ROOT v5.22.00, GEAR v0.12.0 and LCIO v1.11 (or higher). It can be accessed at IN2P3 svn server or my personal webpage `http://llr.in2p3.fr/~ruan/ILDDisplay` with a brief manual.

3.1 Objects to be displayed

3.1.1 Detector geometry

Currently Druid support the ILD full detector geometry with a la Videau HCAL or TESLA HCAL, and the frame work for CALICE test beam geometry. Different subdetectors could be easily mounted and dismounted by interactivly clicking on the GUI.

3.1.2 Event information

Event information is organized into different groups:

MCParticle: MCParticles are displayed as tracks or arrows.

Calorimeter Hit: simulated/digitized calorimeter hits, displayed as cuboids with different size, orientations and color.

Tracker Hit: simulated/digitized tracker hits, displayed as points.

ReconstructedParticle: reconstructed particles are displayed as tracks with the calorimeter hits assigned to this particle.

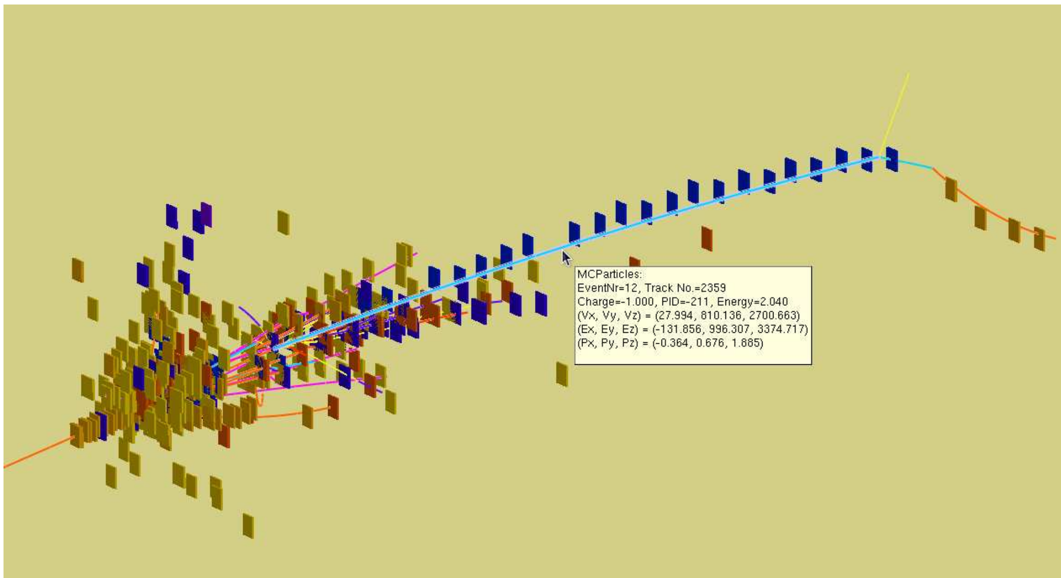


Figure 5: 40 GeV pion shower in the ILD Calorimetry

Here MCParticle and reconstructed particle collection are divided into subgroups according to their PID/energy, and the hits groups are divided into subgroups according to the subdetectors.

Different groups of objects could be hidden/displayed. Druid will remember the status of display/hide for different objects from last event, and keep the status when navigated to a new event. By default, Druid will always display the new object.

3.2 Display options

Druid display could be easily zoomed, rotated and shifted by the mouse. With a self defined GUI pannel, lots of interactive actions are supported in DRUID.

3.2.1 Individual objects

TEve allows us to attach text information on individual objects, which could be readout by picking up the object with the mouse.

The rotation center could be selected, together with the zoom option, you can have a very closed and clear view of event details. Fig. 5 shows the shower created by 40GeV Pion, with the Monte Carlo truth information of the secondary particles generated inside the hardonic shower. Where you can see a 2.04GeV Pion is generated in the interaction, and pass through the HCAL as a mip.

3.2.2 Option for calorimeter hits

Druid allows various of options for the size and color of calorimeter hits, which could be specified in the option pannel. For example, simulated calorimeter hit could be coloured

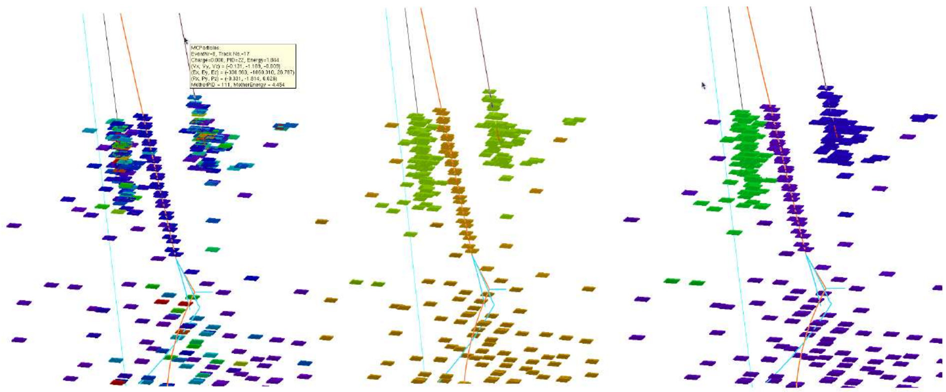


Figure 6: Tau jet $\tau \rightarrow \nu + \pi^0 + \pi^+$ with different color options: from left to right, energy, track ID and random index on track

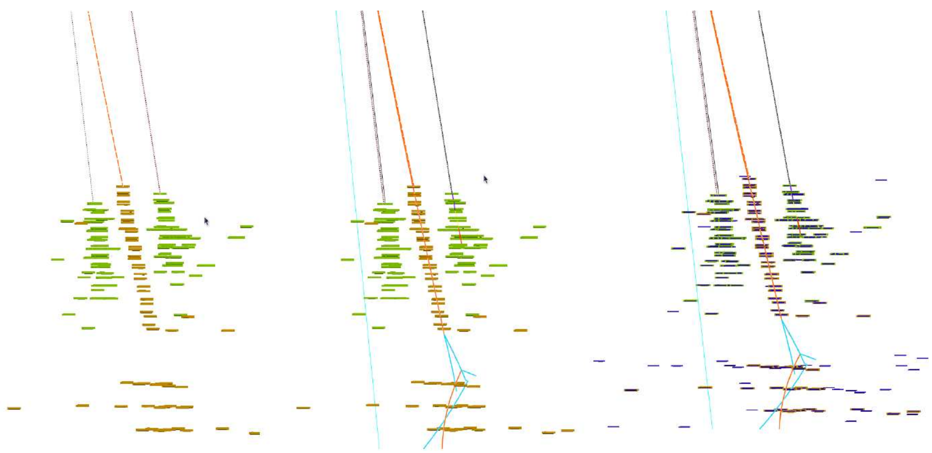


Figure 7: Tau jet $\tau \rightarrow \nu + \pi^0 + \pi^+$ at MCTruth and Reconstruction level

according to the hit energy, the PDG of MCParticle that passing through or at the vertex (as origin), or a randomly generated color. As for the reconstructed particle assigned calorimeter hit, it could be coloured to the PDG information of reconstructed particle.

Fig. 6 shows how a τ jet looks like with different color option (at MC truth level).

3.3 Analysis reconstruction algorithm performance

By comparing the Monte Carlo truth objects and the digitized/reconstructed objects, DRUID provides a platform to analysis the reconstruction software performance.

Fig. 7 shows an example with the same τ jet at MC truth and reconstruction level. The left one is the reconstructed particle tracks (using PandoraPFA) with assigned calorimeter hits, where you can see Pandora found two gamma and one pion; The middle one overlay the MCParticle information, thus we know that Pandora is right about the gammas and pions, also some secondary particles generated inside the shower and the neutrino could be

found. The right one overlay the simulated calorimeter hits: some simulated calorimeter hits are dropped during the digitization/reconstruction. You can easily tell if this dropping is expected or not by reading the text information attached to each of those hits.

3.4 Conclusion

As a solid option for the ILC, the software development of GRPC SDHCAL technology is progressing at steady pace with the hardware developments.

The first order of digitization module has been developed, and the preliminary result shows that SDHCAL can record more information than the DHCAL, ensures better performance.

The display package DRUID has been developed, with which people could get better understanding to the ILD/test beam event as well as to the performance of reconstruction algorithms.

The digitization module will be upgraded with realistic physics efforts (saturation, efficiency and multiplicity) and the DRUID will be updated with new geometries. As a central task for Semi DHCAL software development, people are currently foucs on the design of reconstruction algorithm, which will be integrated into the PandoraPFA reconstruction framework.

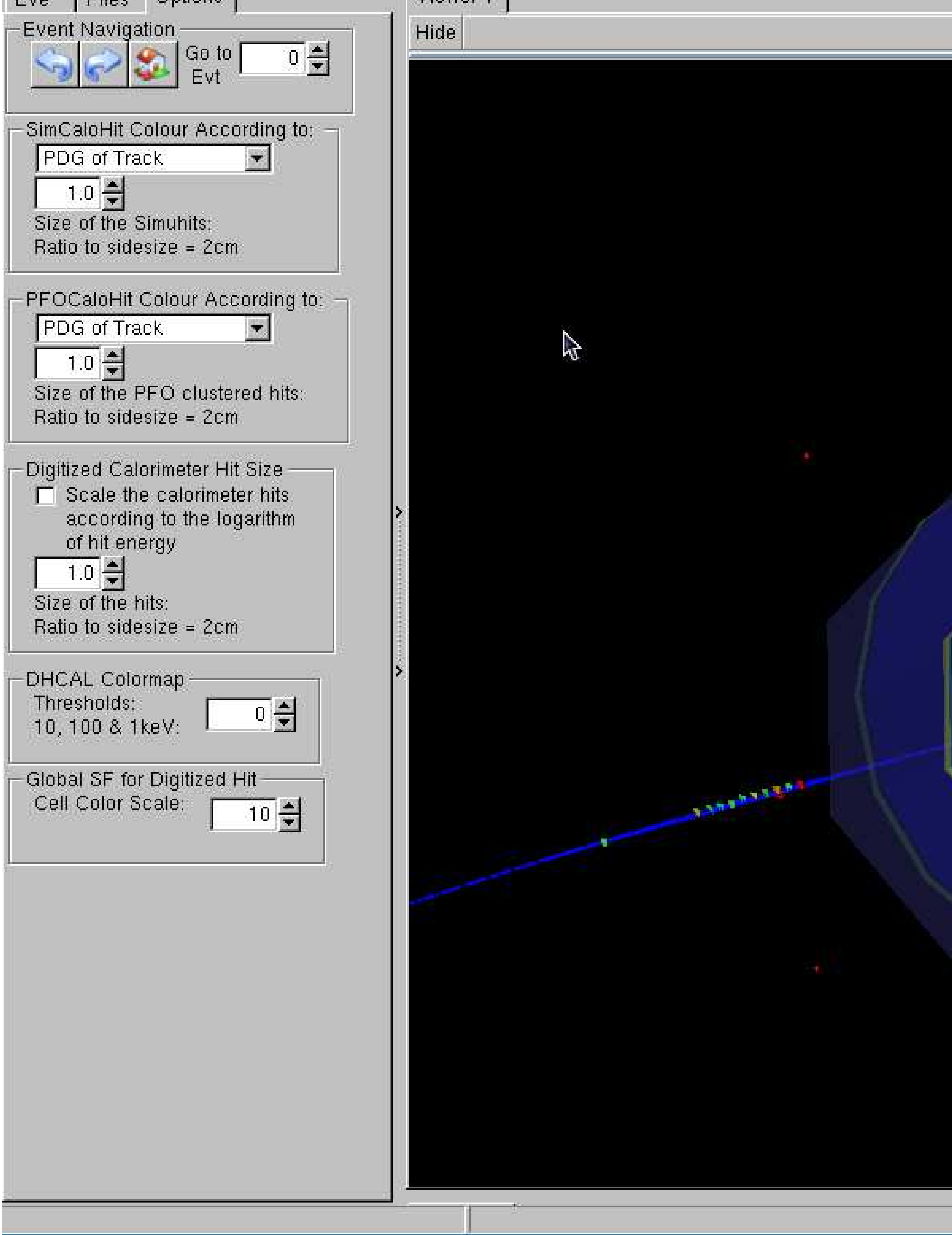
4 Bibliography

References

[1] http://www.hep.phy.cam.ac.uk/~thomson/pandoraPFA

[2] http://root.cern.ch

[3] http://llr.in2p3.fr/~ruan/ILDDisplay/DruidNote.pdf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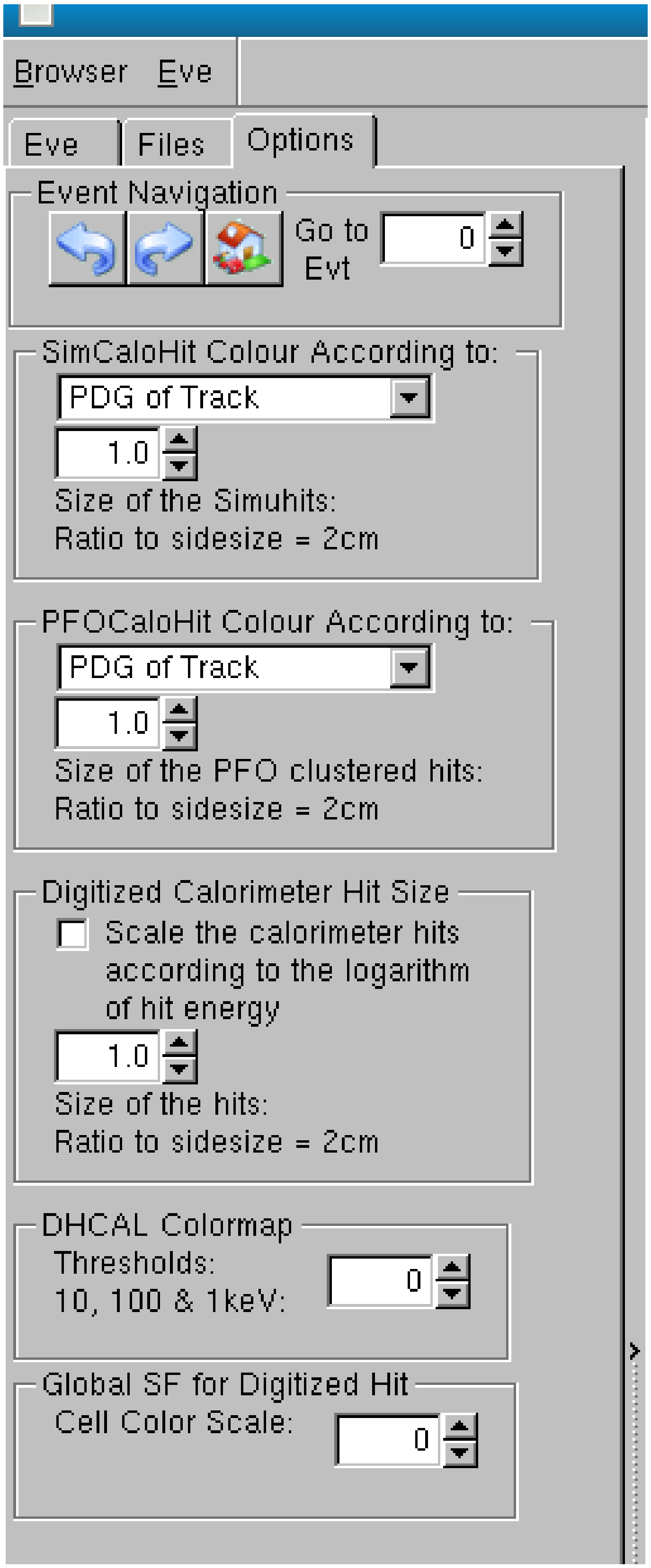
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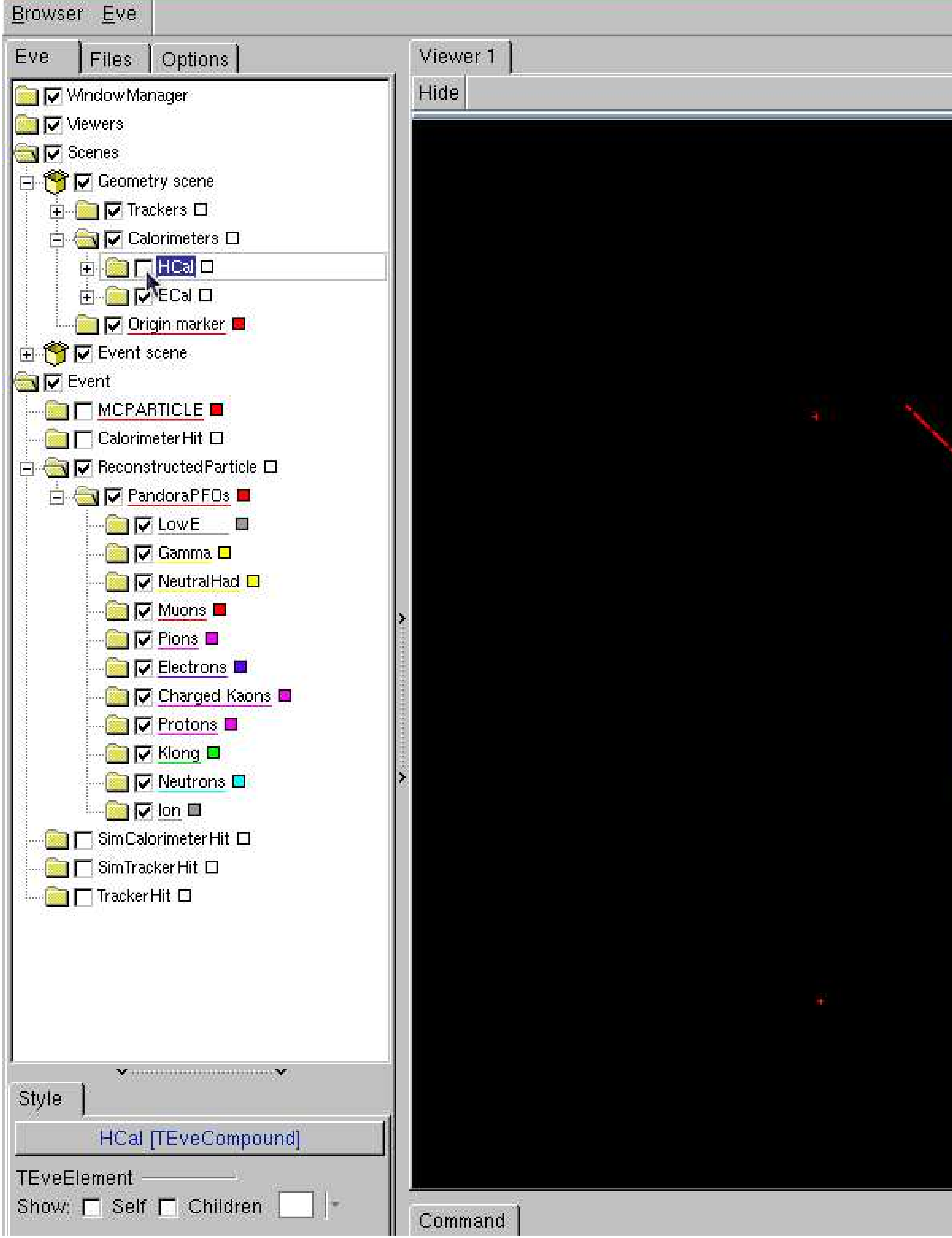
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